



Deformable trailing edge geometries and cyclic pitch controller

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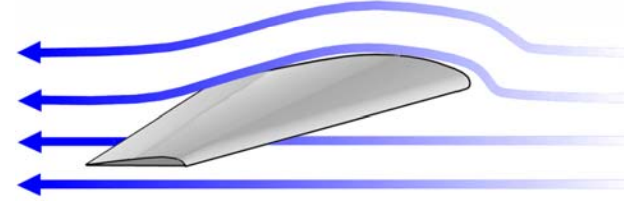
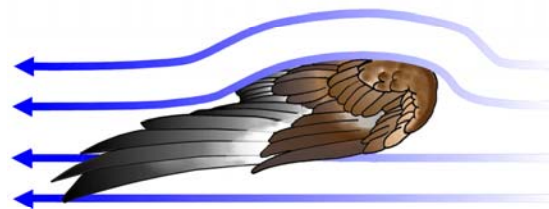
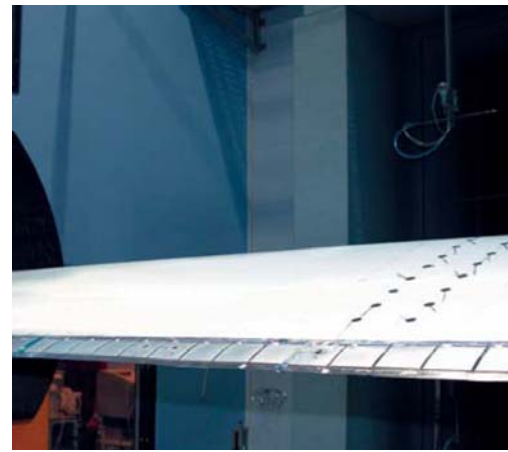
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 Introduction 
Controller
Results
Conclusion



- **1958** Inaugurated. Purpose: Peaceful utilisation of nuclear energy
- **1976** Oil crises (1973) results in research in other Energy sources
- **1978** Research in Wind Energy starts
- **1985** Political decision of not having nuclear energy in Denmark
- **1994** State-owned enterprise
- **2000** The last nuclear reactor is shut down
- **2007** Merger with DTU, the Danish Institute for Food and Veterinary Research, the Danish Institute for Fisheries Research, the Danish National Space Centre and the Danish Transport Research Institute

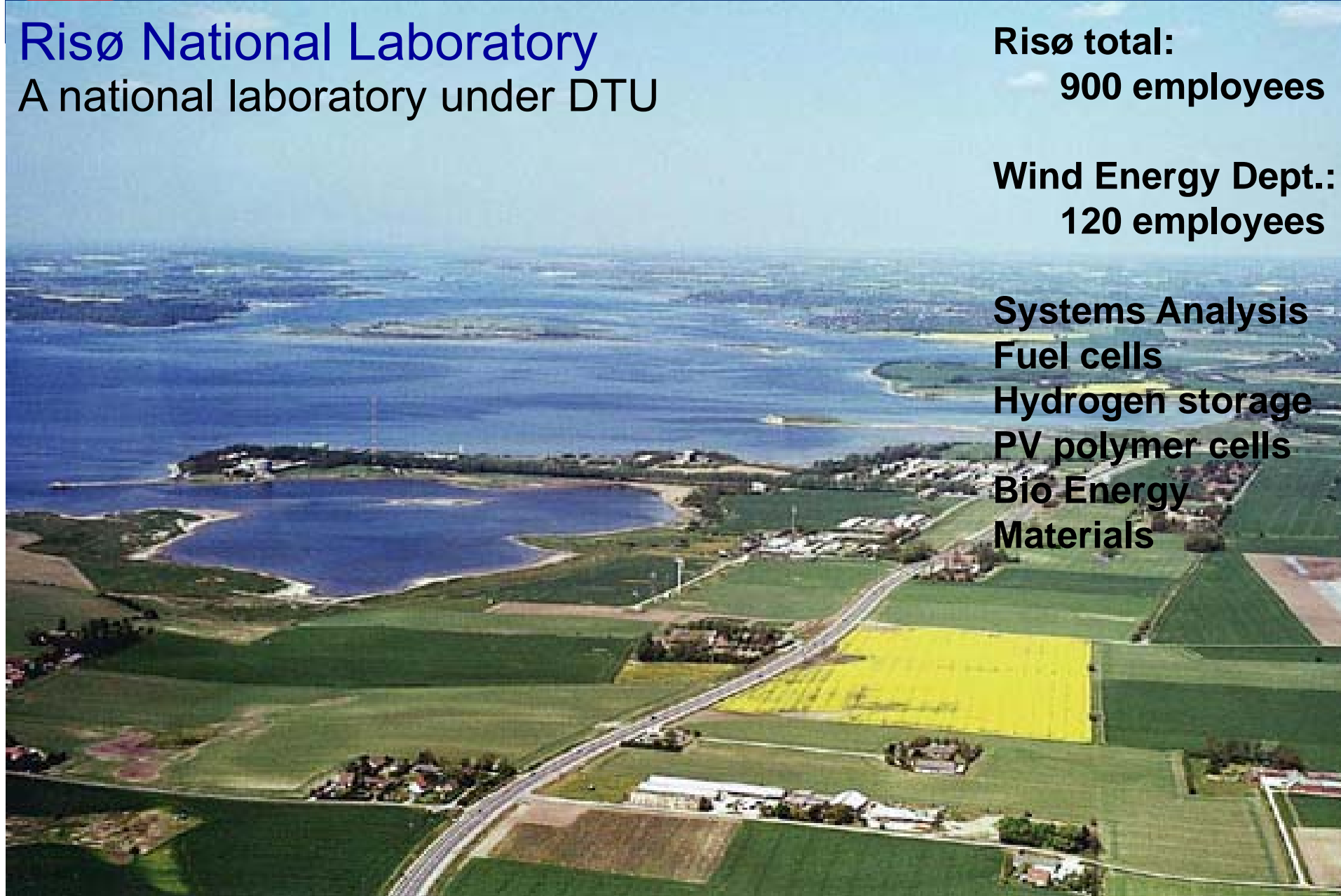
Risø National Laboratory

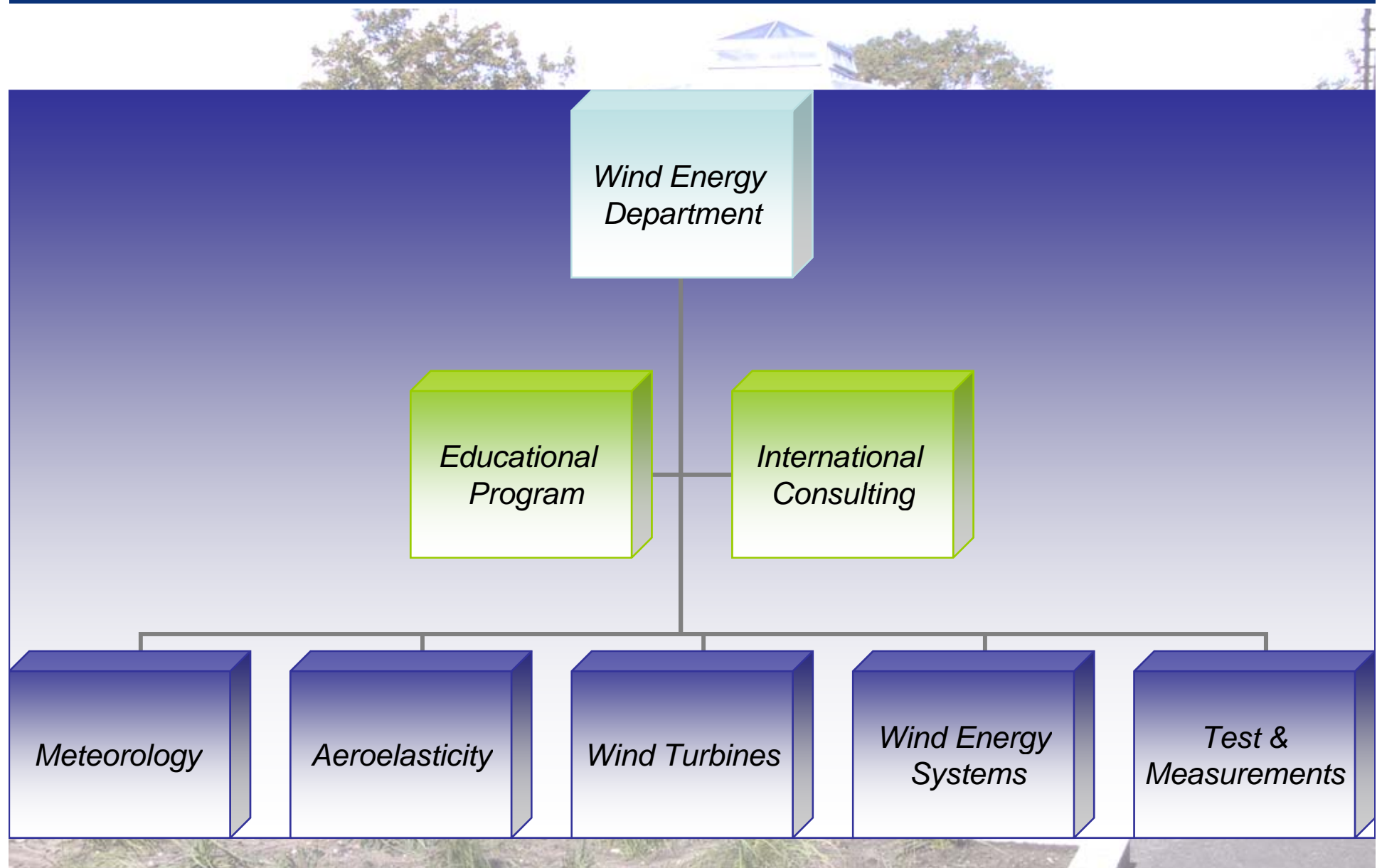
A national laboratory under DTU

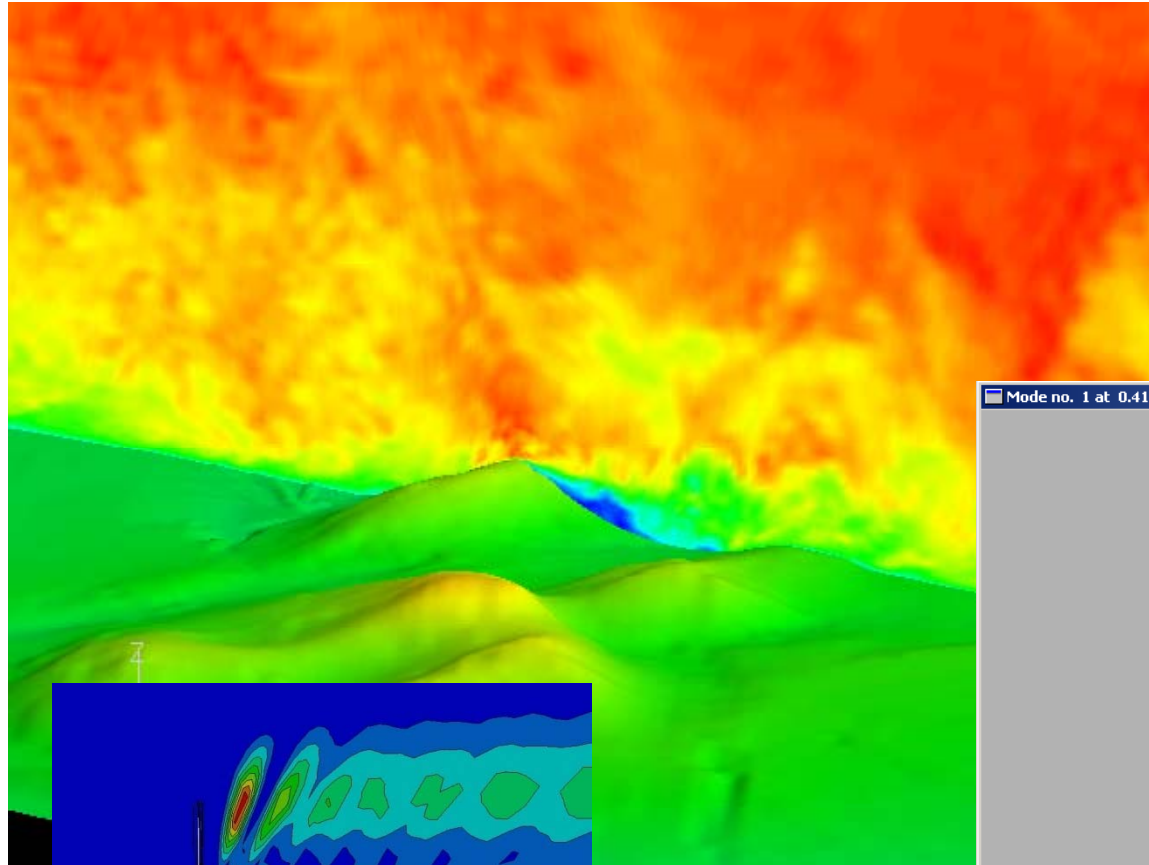
Risø total:
900 employees

Wind Energy Dept.:
120 employees

Systems Analysis
Fuel cells
Hydrogen storage
PV polymer cells
Bio Energy
Materials





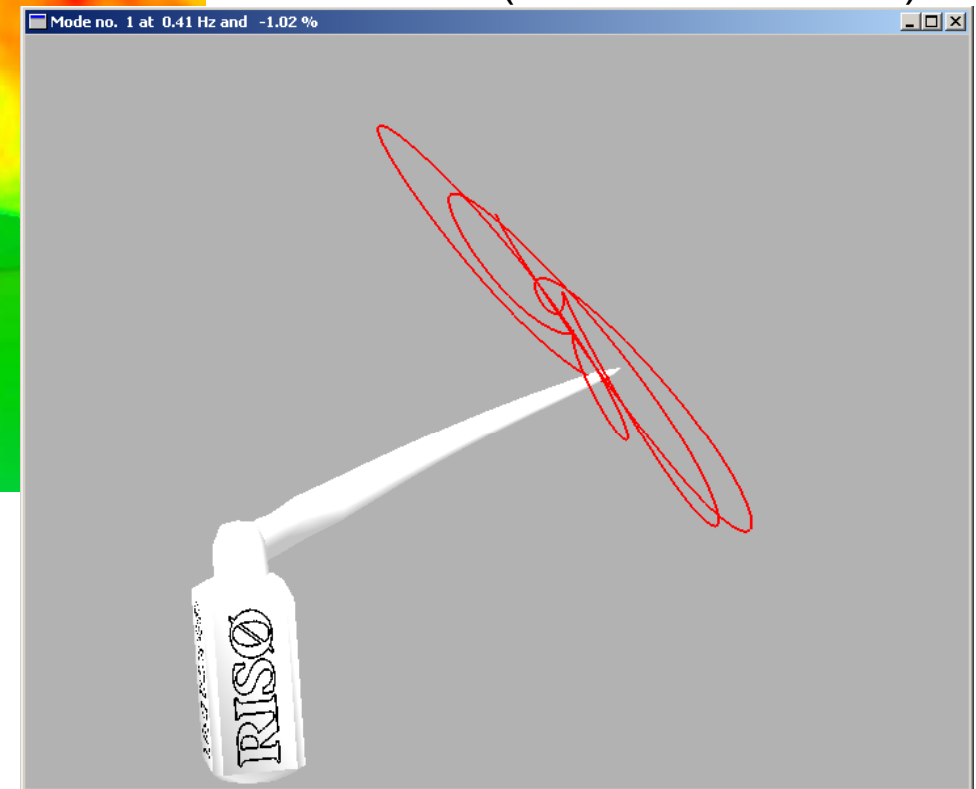
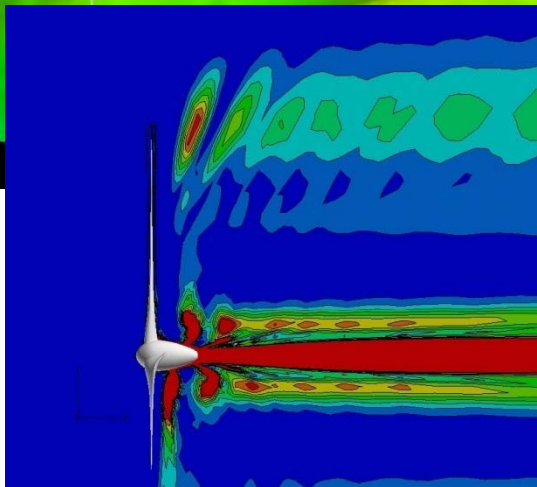


EllipSys (2D and 3D)

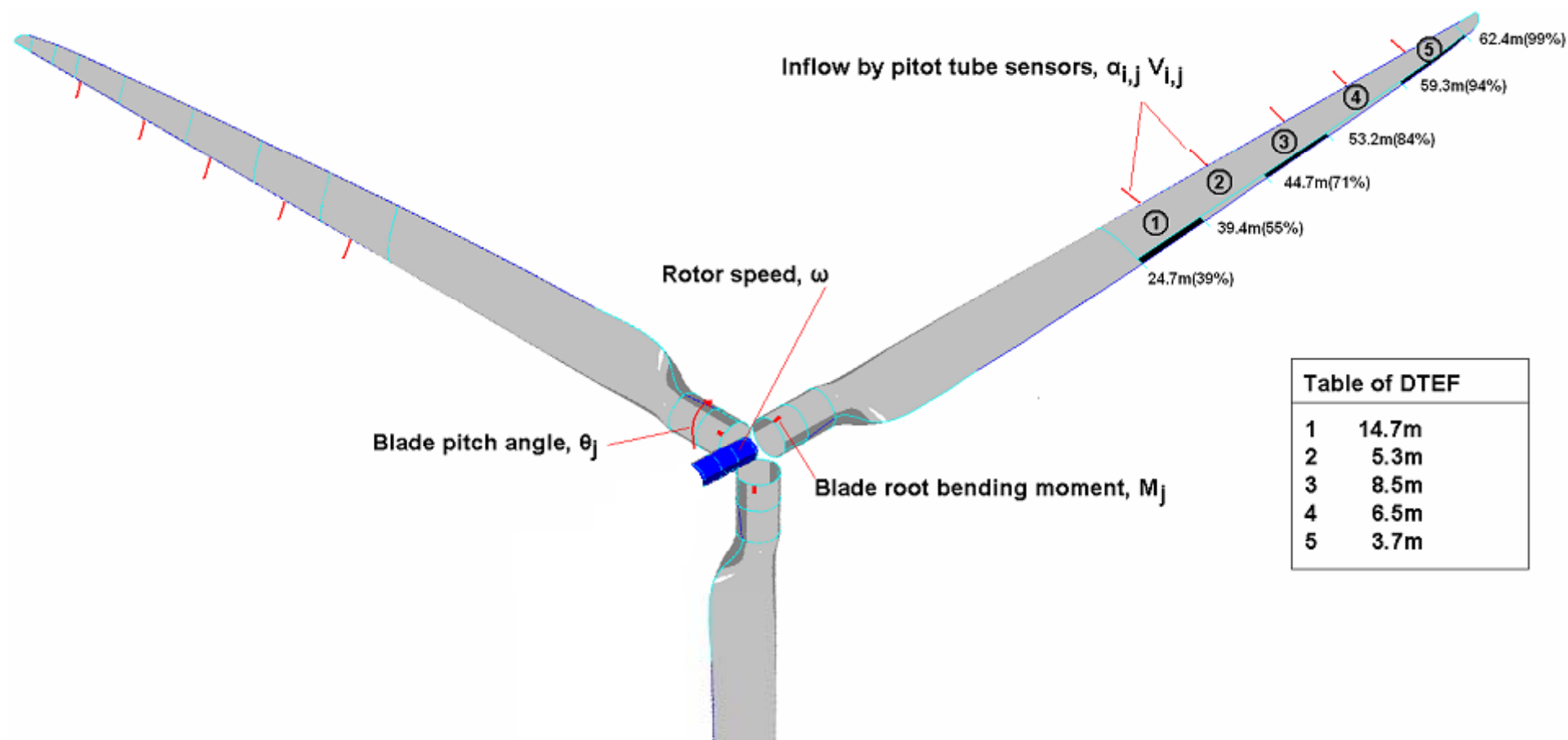
HAWC2 (and HAWC)

HAWTOpt

HAWCStab (soon HAWCStab2)



Sensors and DTEG positions



Peter B. Andersen, Mac Gaunaa, Christian Bak, Helge Aa. Madsen
 Frederik Zahle, Joachim Heinz, Leonardo Bergami, Li Na, Andreas Fisher

DTEG Property assumptions:

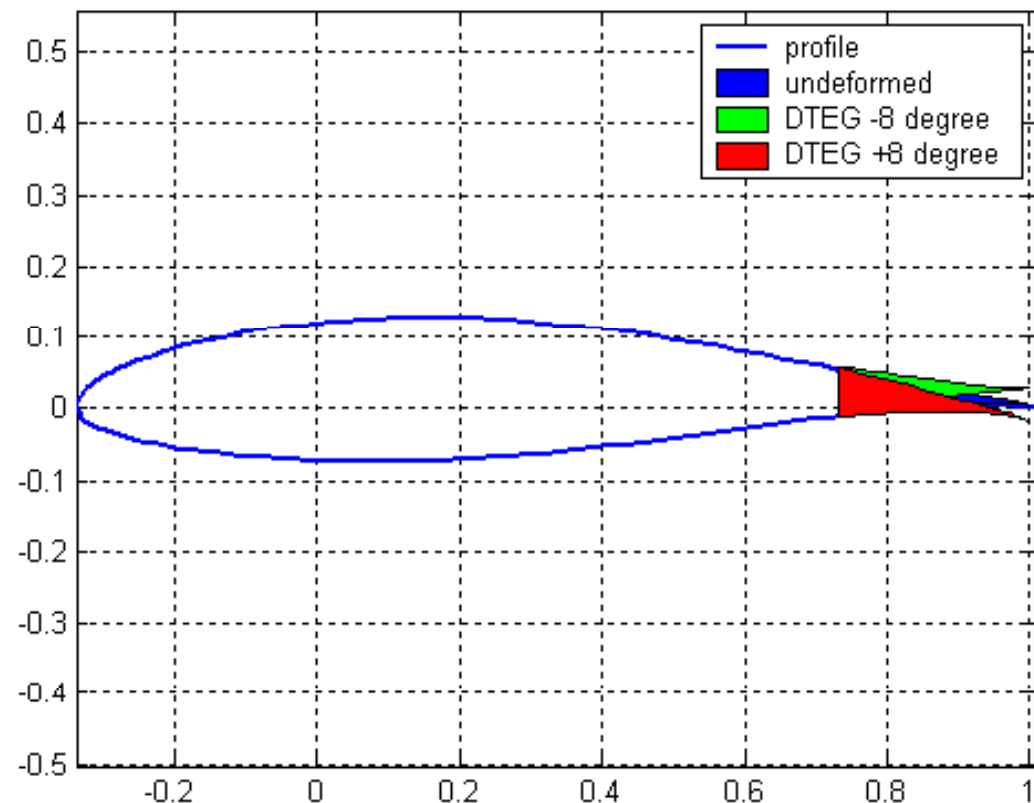
10% of chord

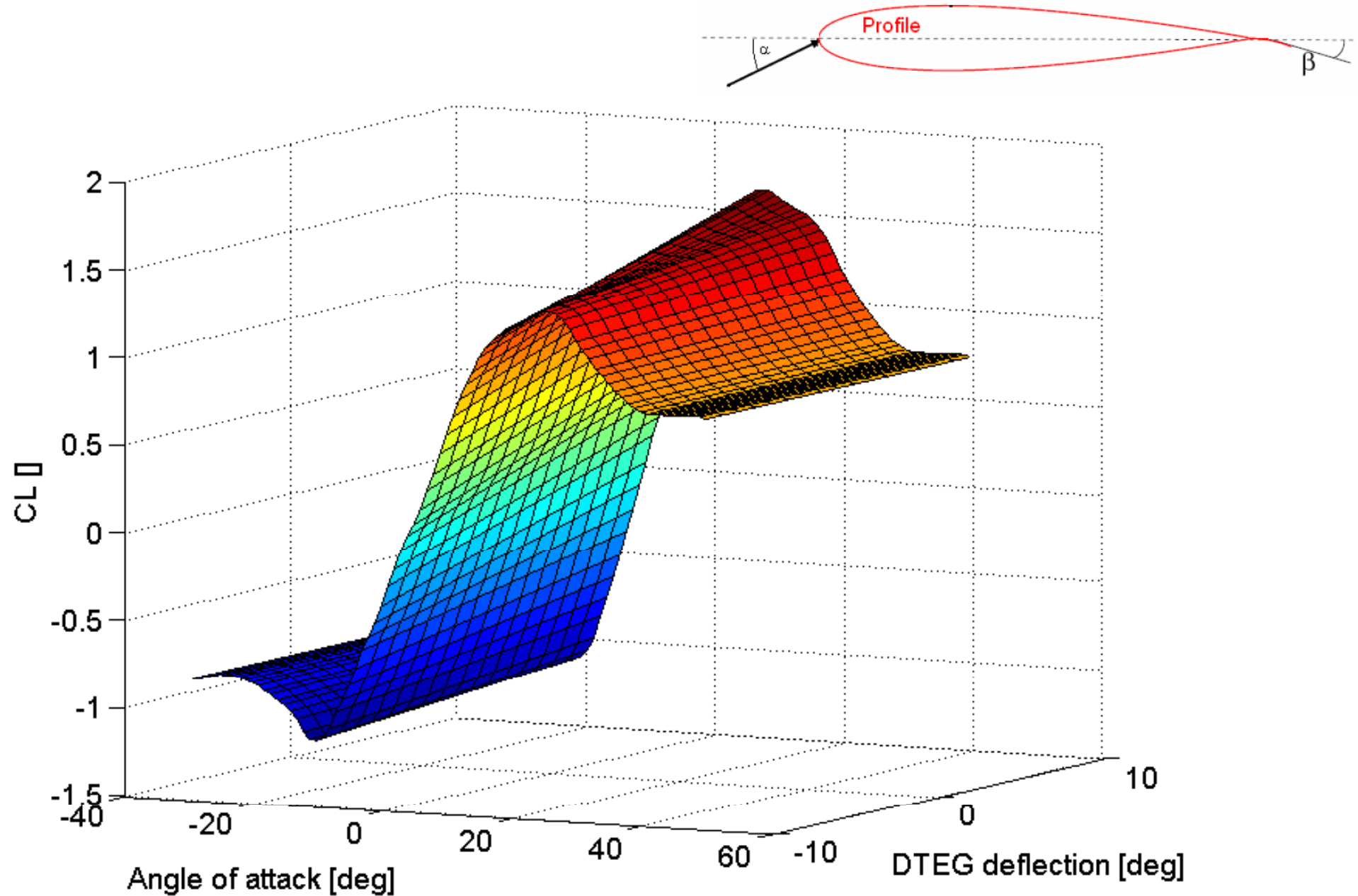
+/- 8 degree deflection possible

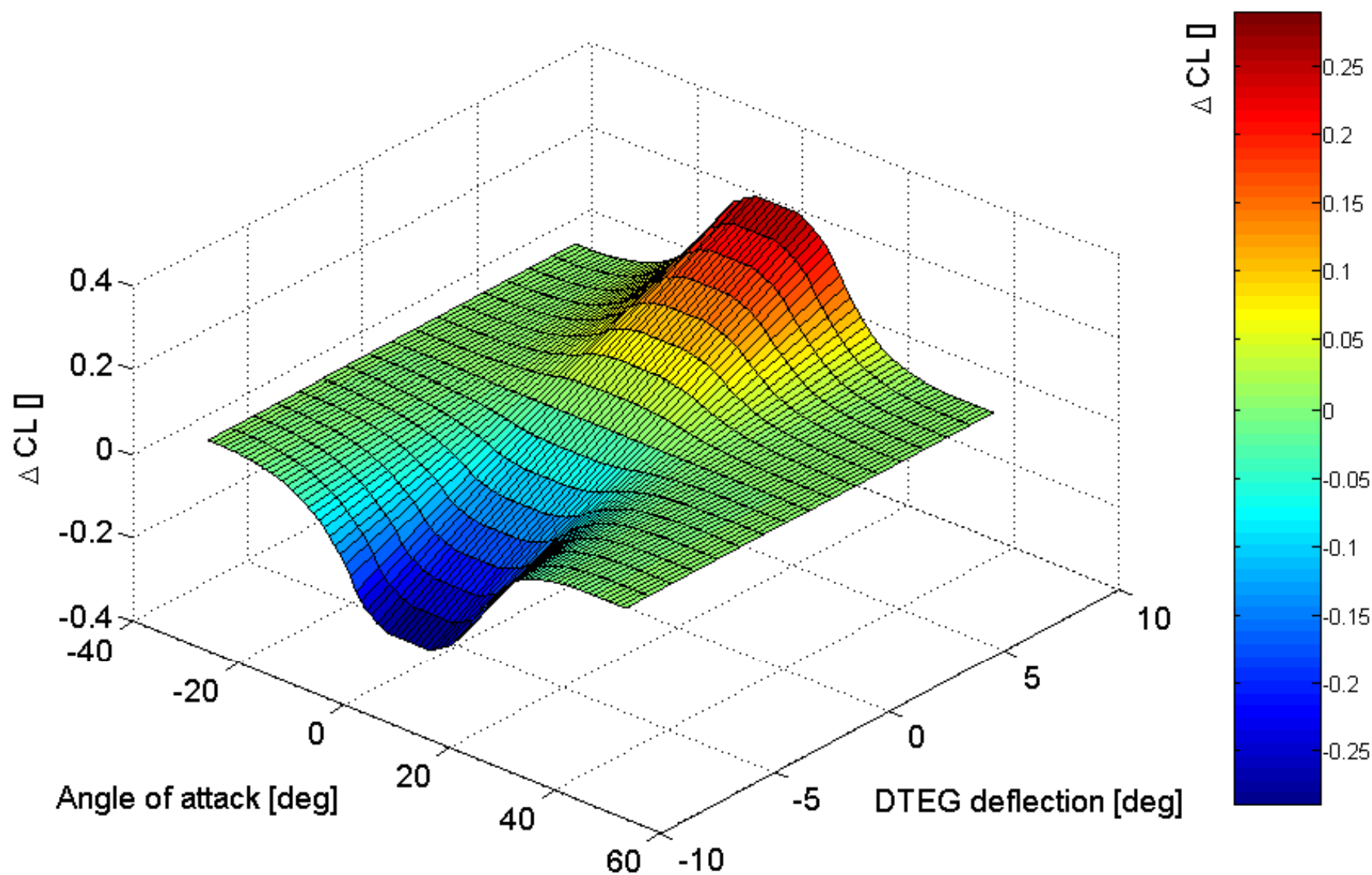
from +/-8 to -/+8 in simulated "dt" (=0.01s)

no effects of hysteresis



no overshoot or other dynamics

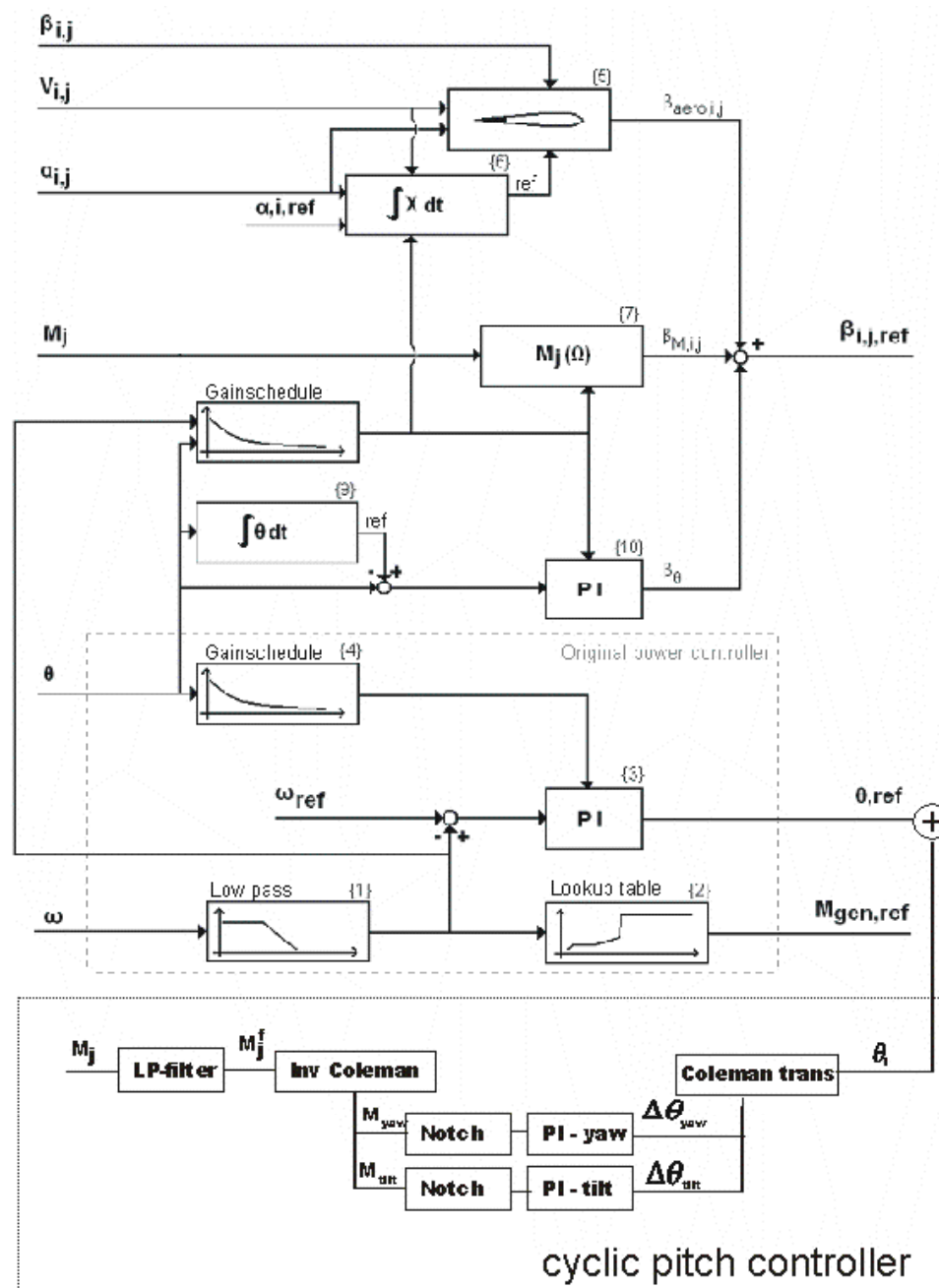
 $\max \Delta CL(\alpha, \beta=8\text{deg}) = 0.29$ $\min \Delta CL(\alpha, \beta=-8\text{deg}) = -0.29$ 







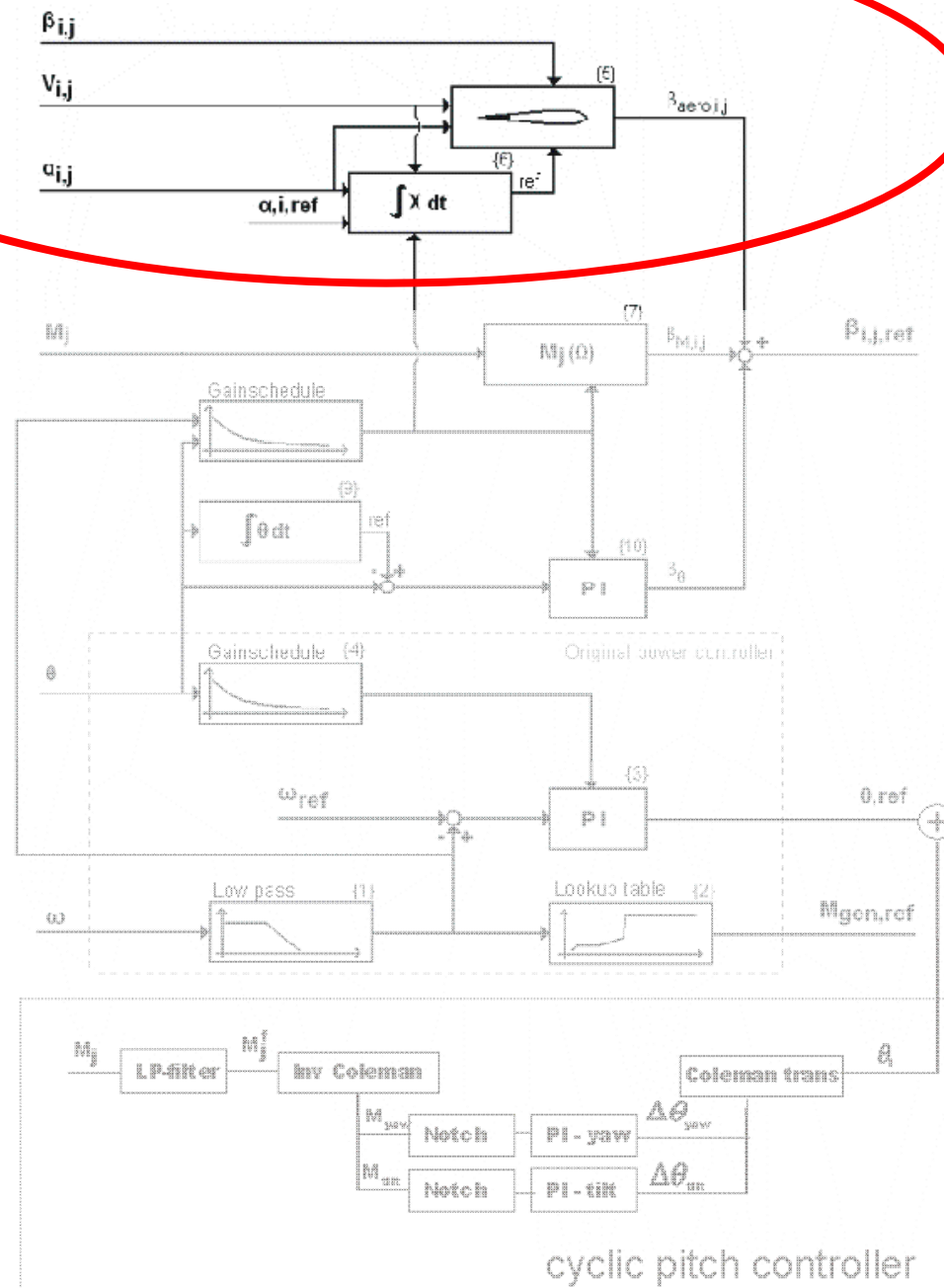
Introduction
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An "inverse"
Theodorsen/Gaunaa
model

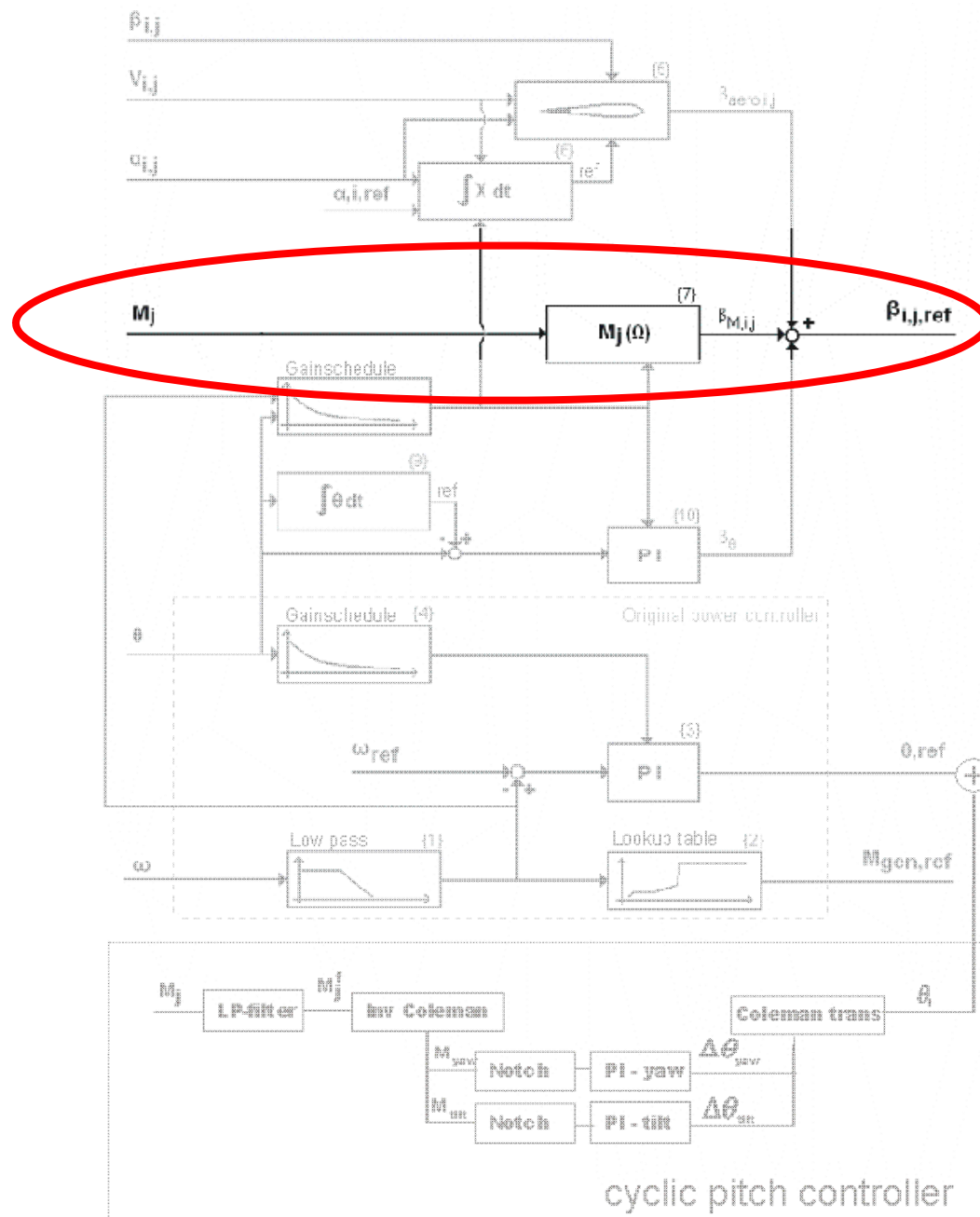
Possibility to use
running averages or
reference AOA values.
(The K_α factor)

Objective: level out
"stochastic" signal
AOA / Vrel



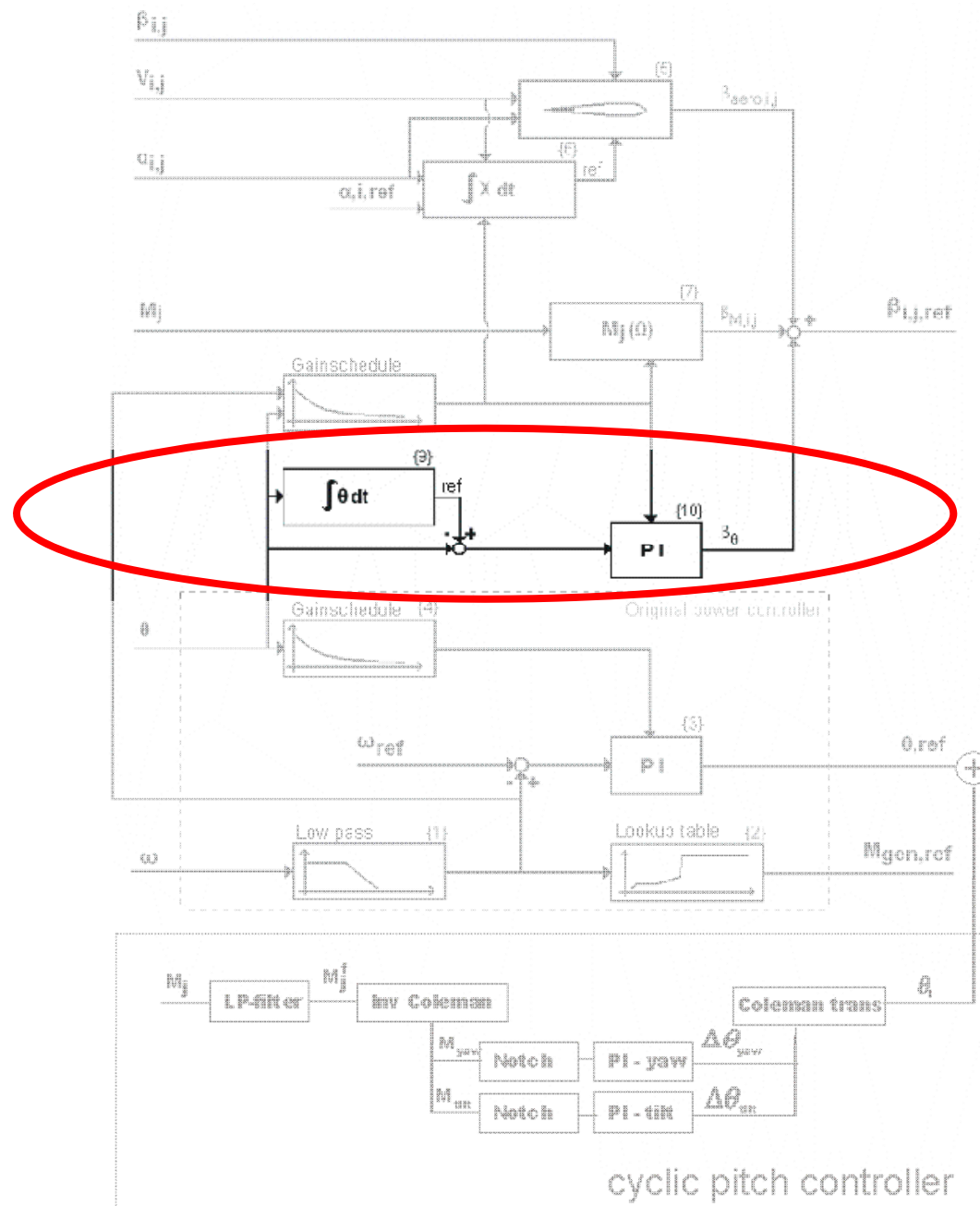
An elastic response model

Objective: level out
“deterministic” signal
 M_j (blade root moment)



Pitch communication model

Objective: DTEG and
blade pitch work together

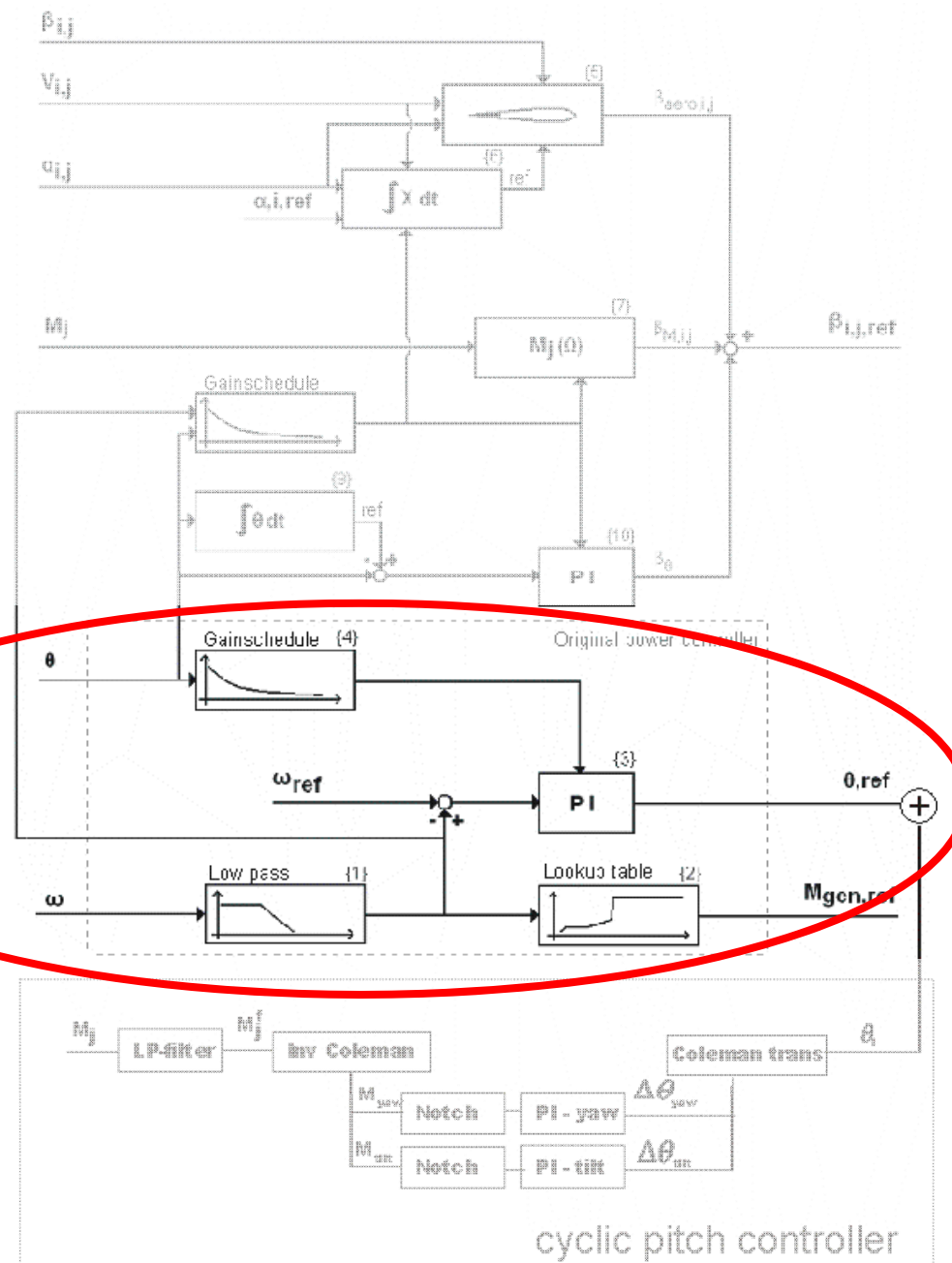


pitch servo modeled as
a 2nd order system

max pitch rate: 8
degree/sec

Power controller model:

Omega filter to remove
"free-free" oscillations



Cyclic pitch controller

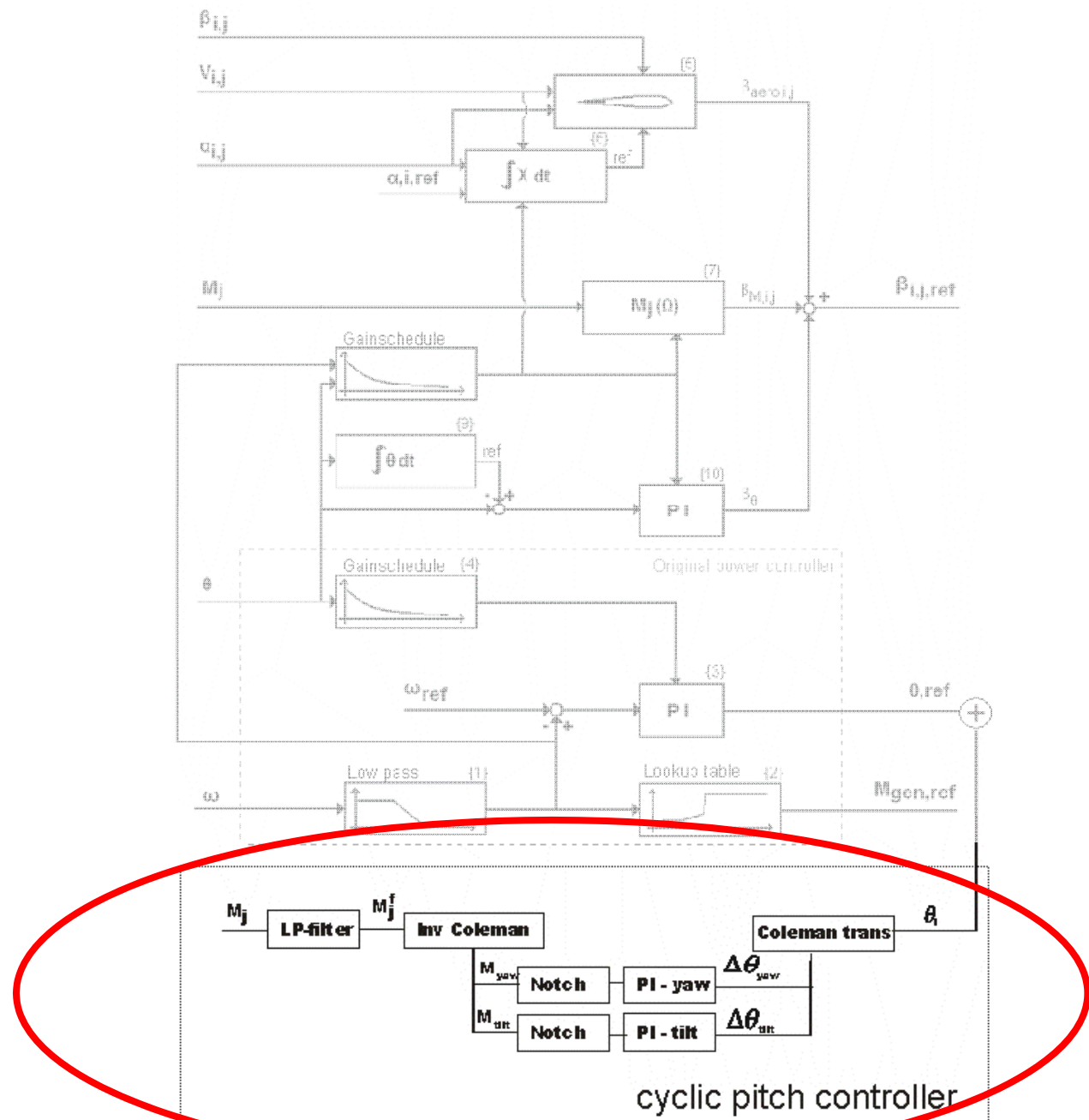
Invers Coleman transformation

Notch filter

PI on yaw and tilt

Coleman transformation

additional pitch angle
output





Introduction

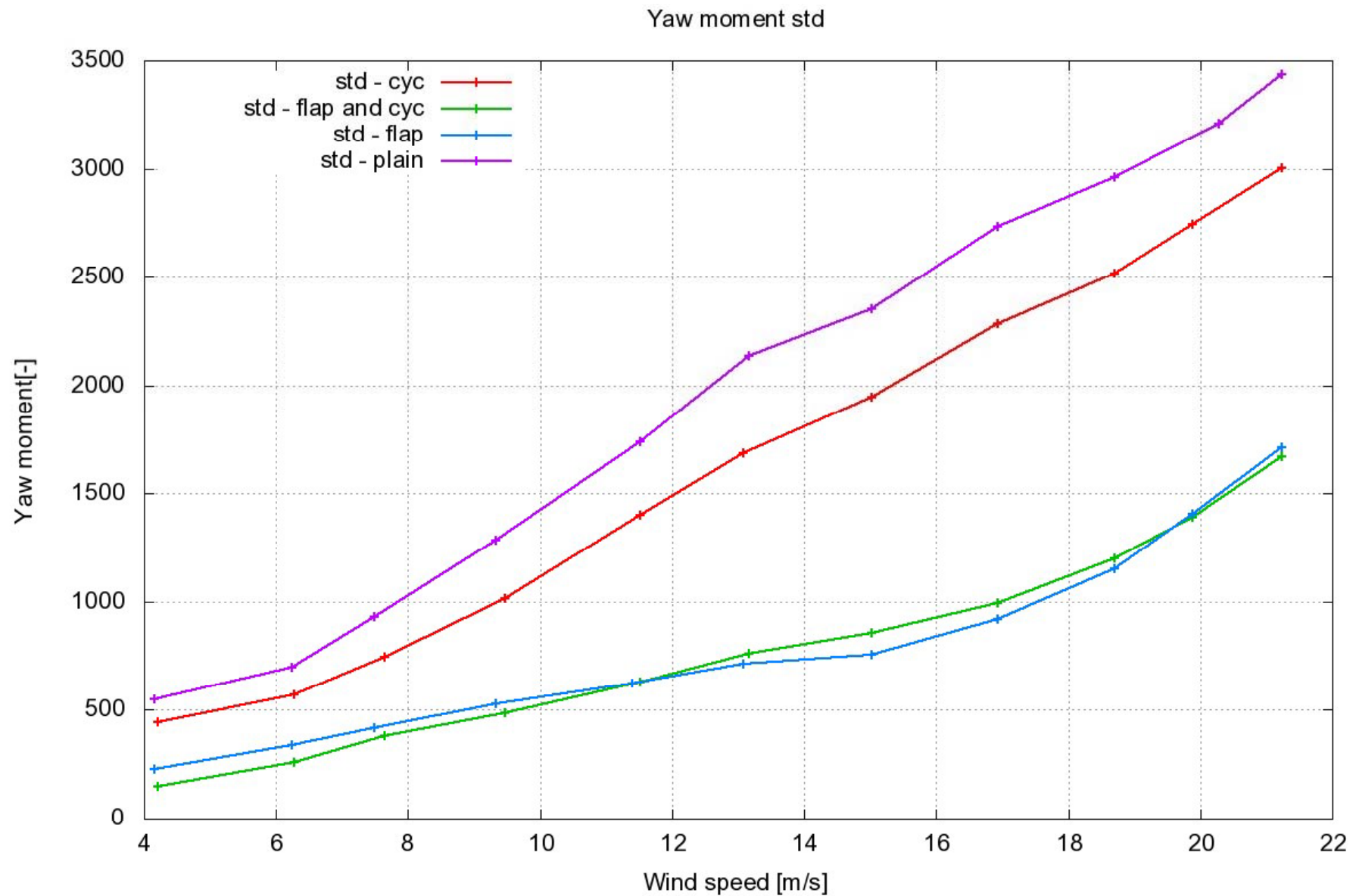
Controller

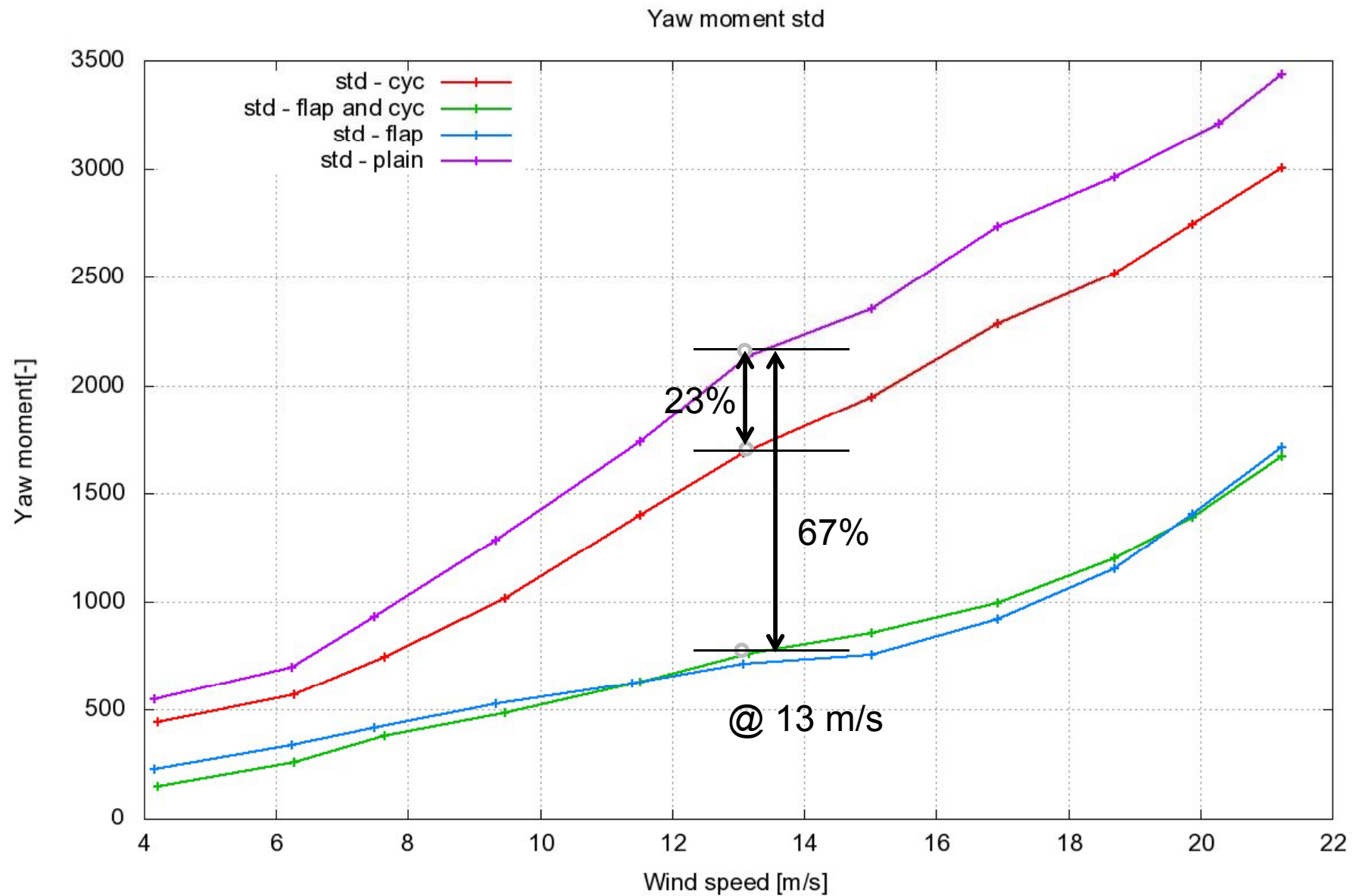


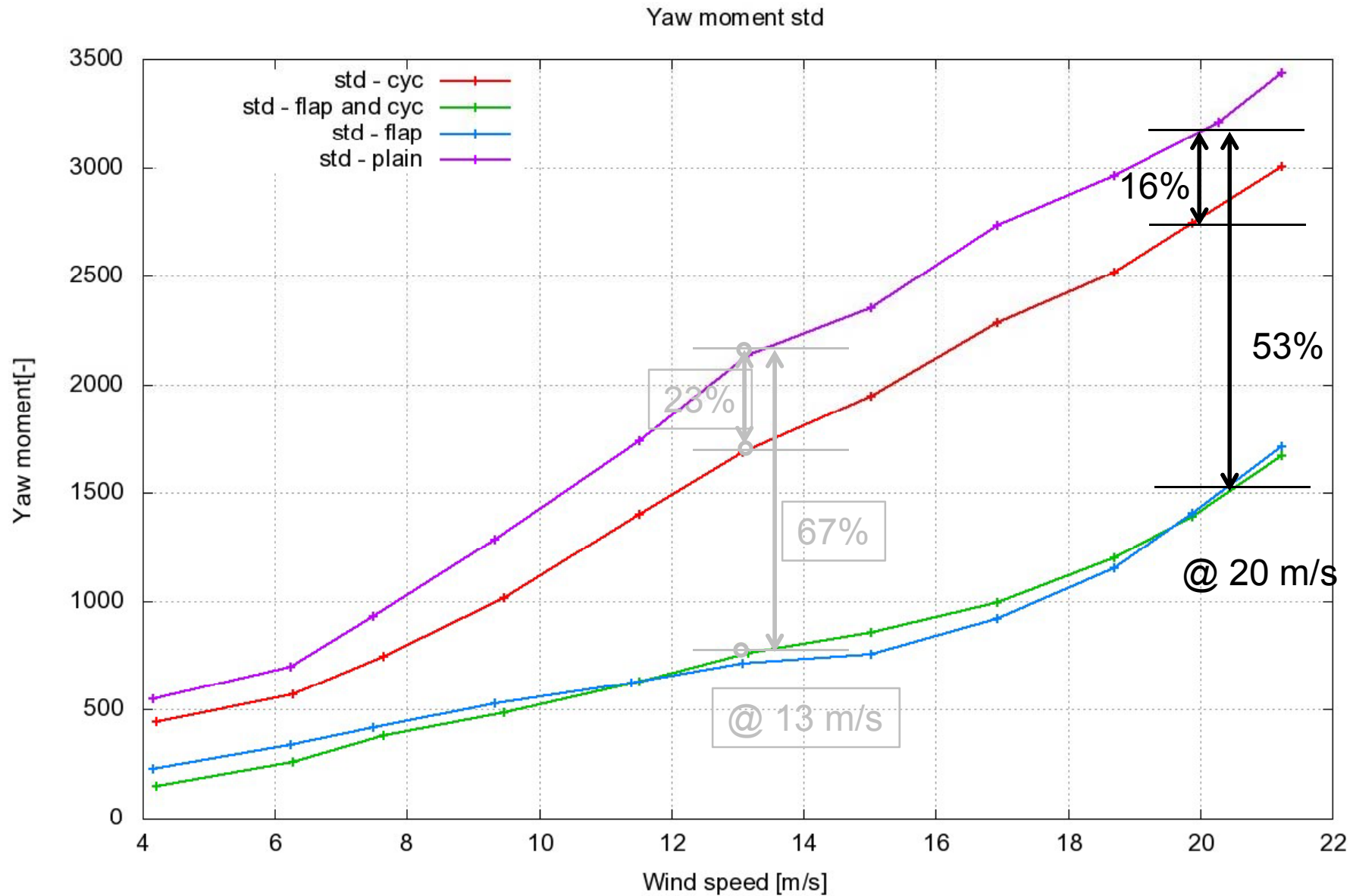
Results

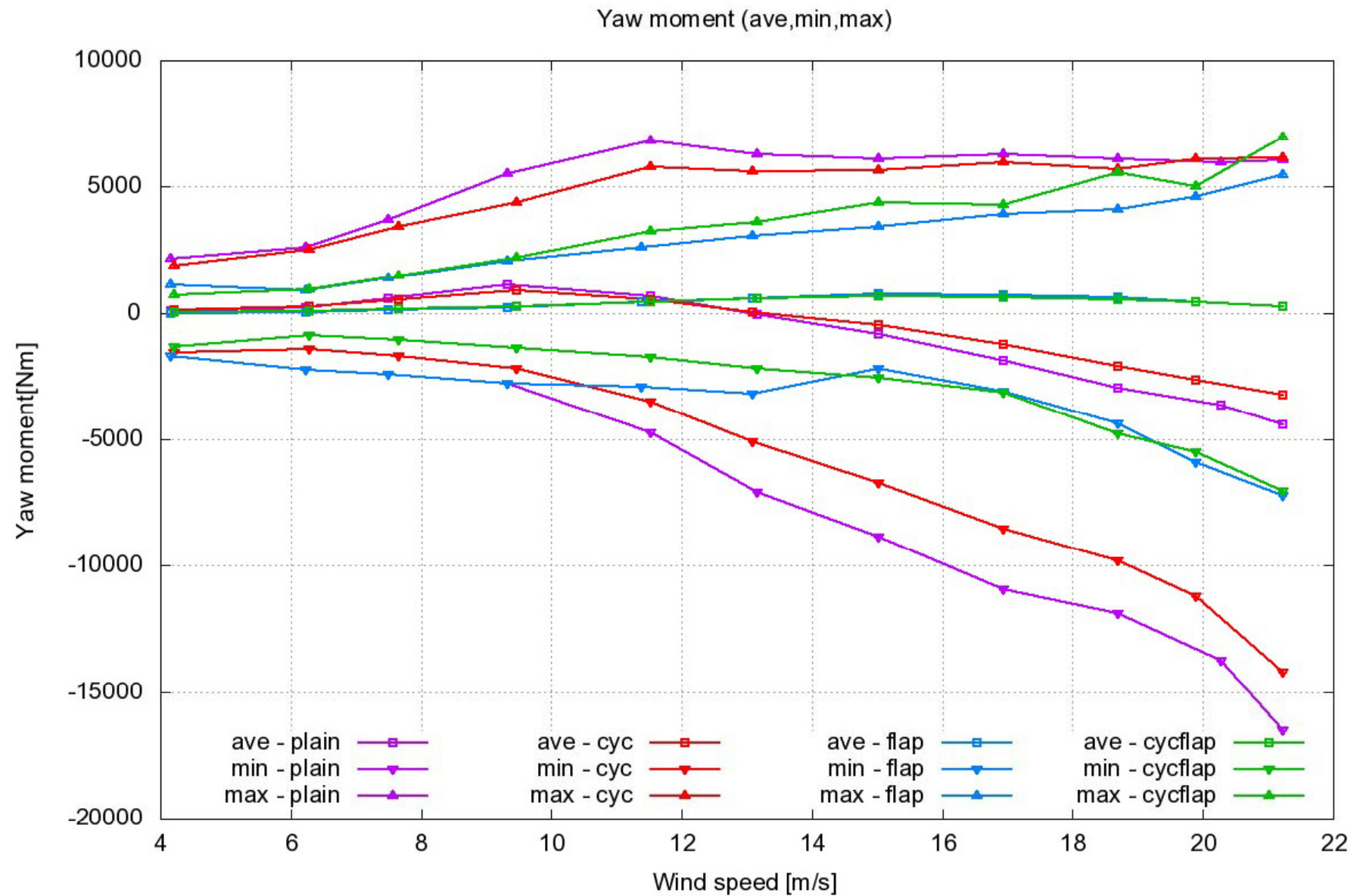


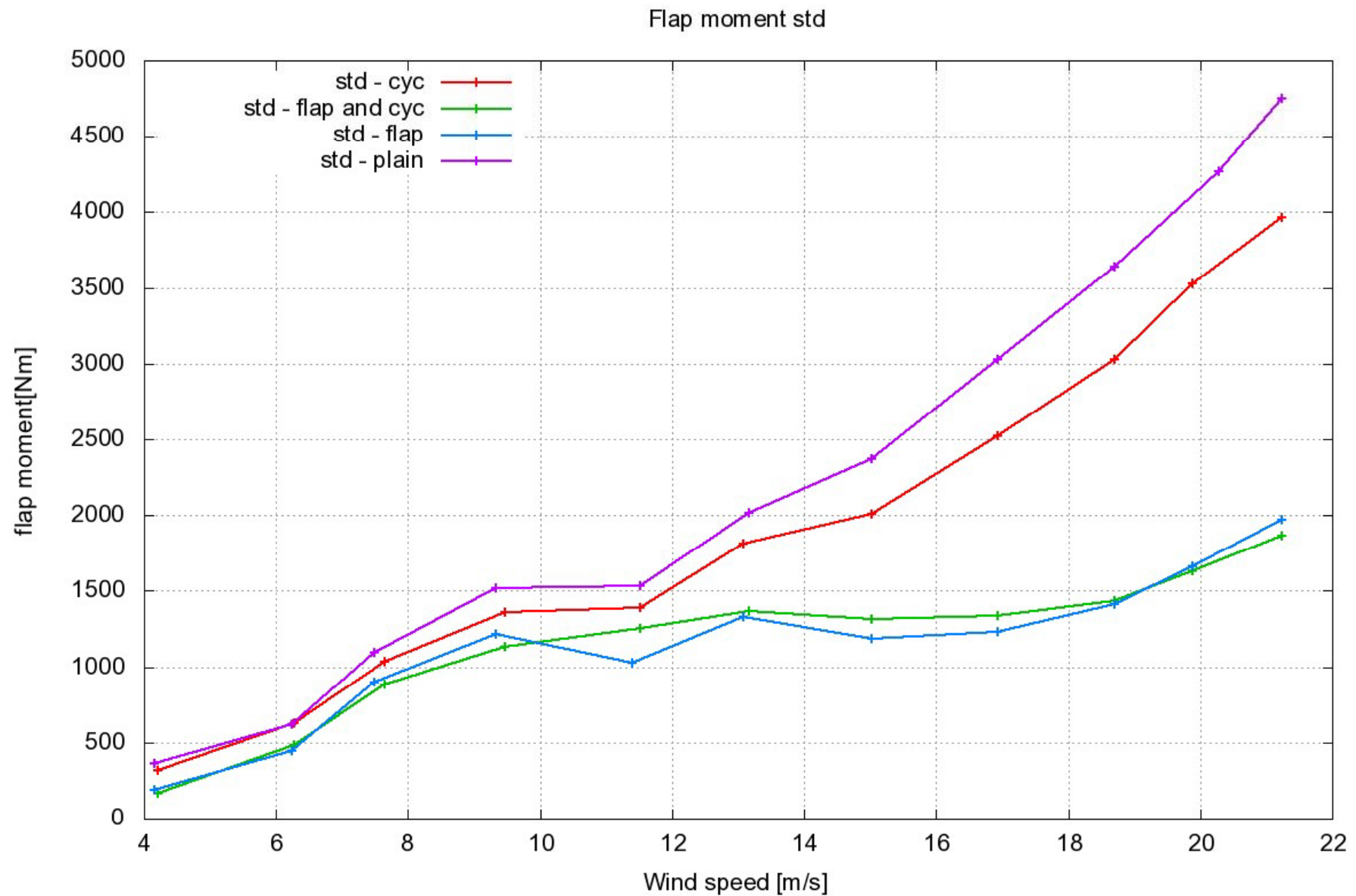
Conclusion

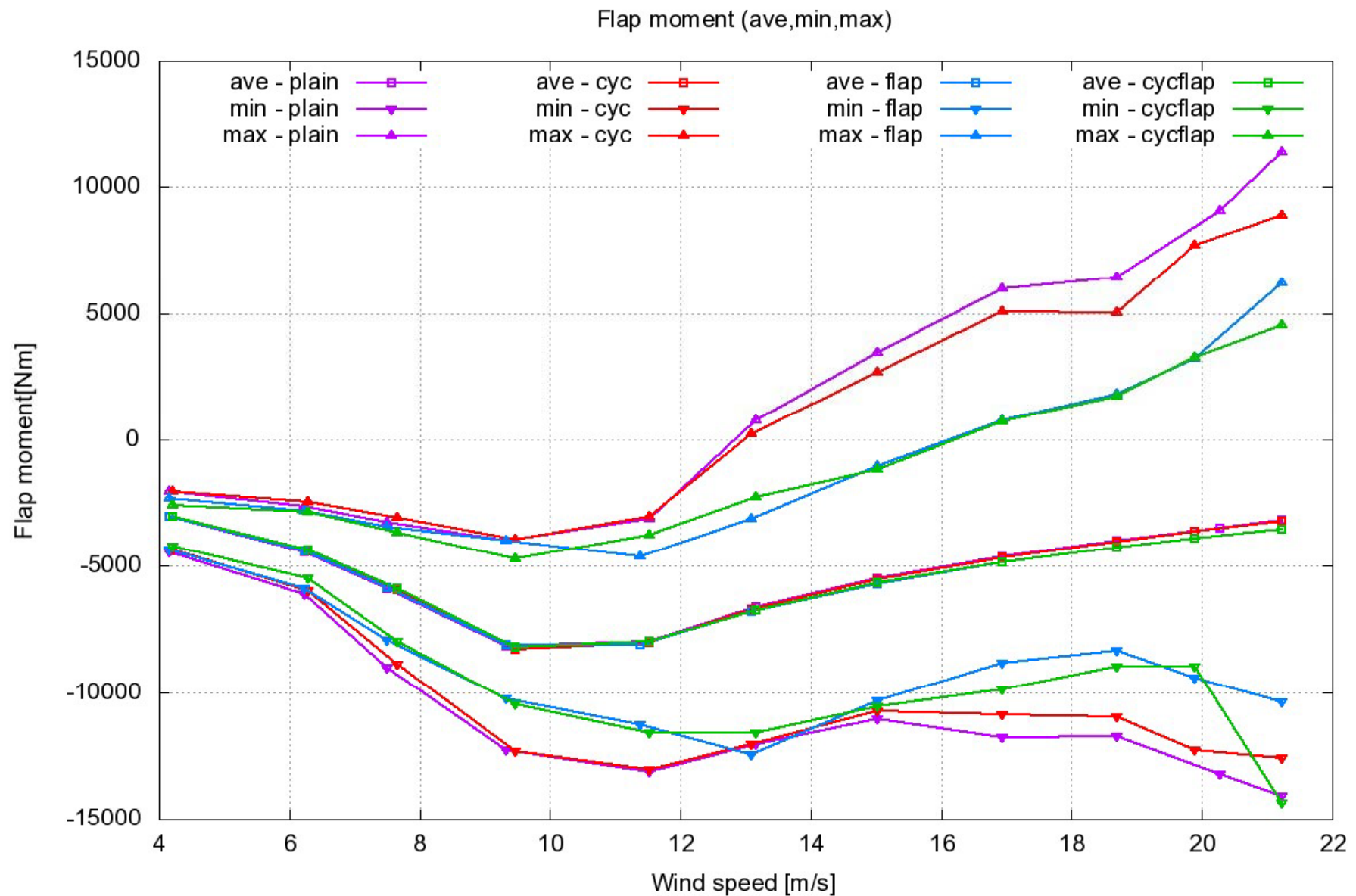


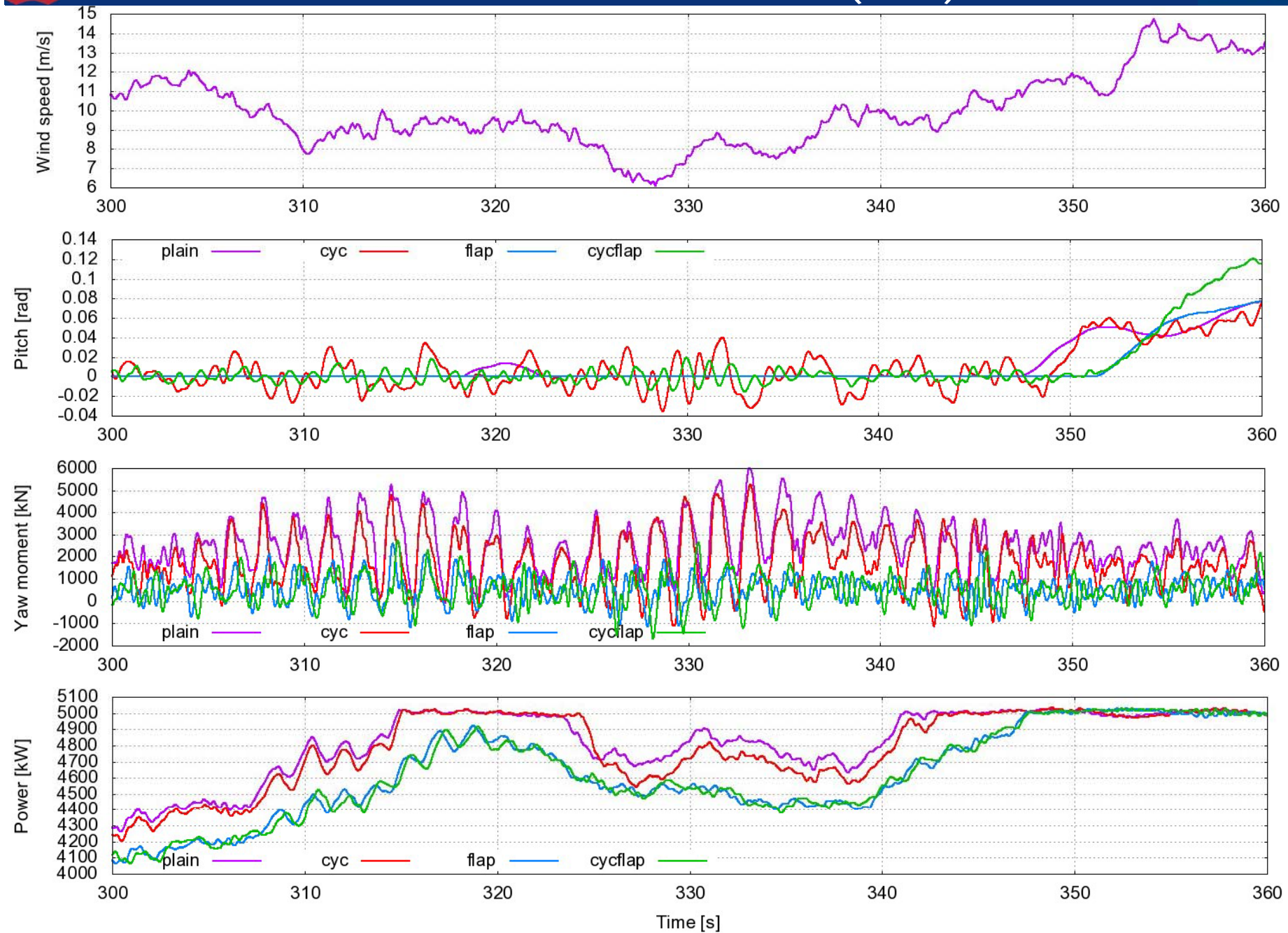


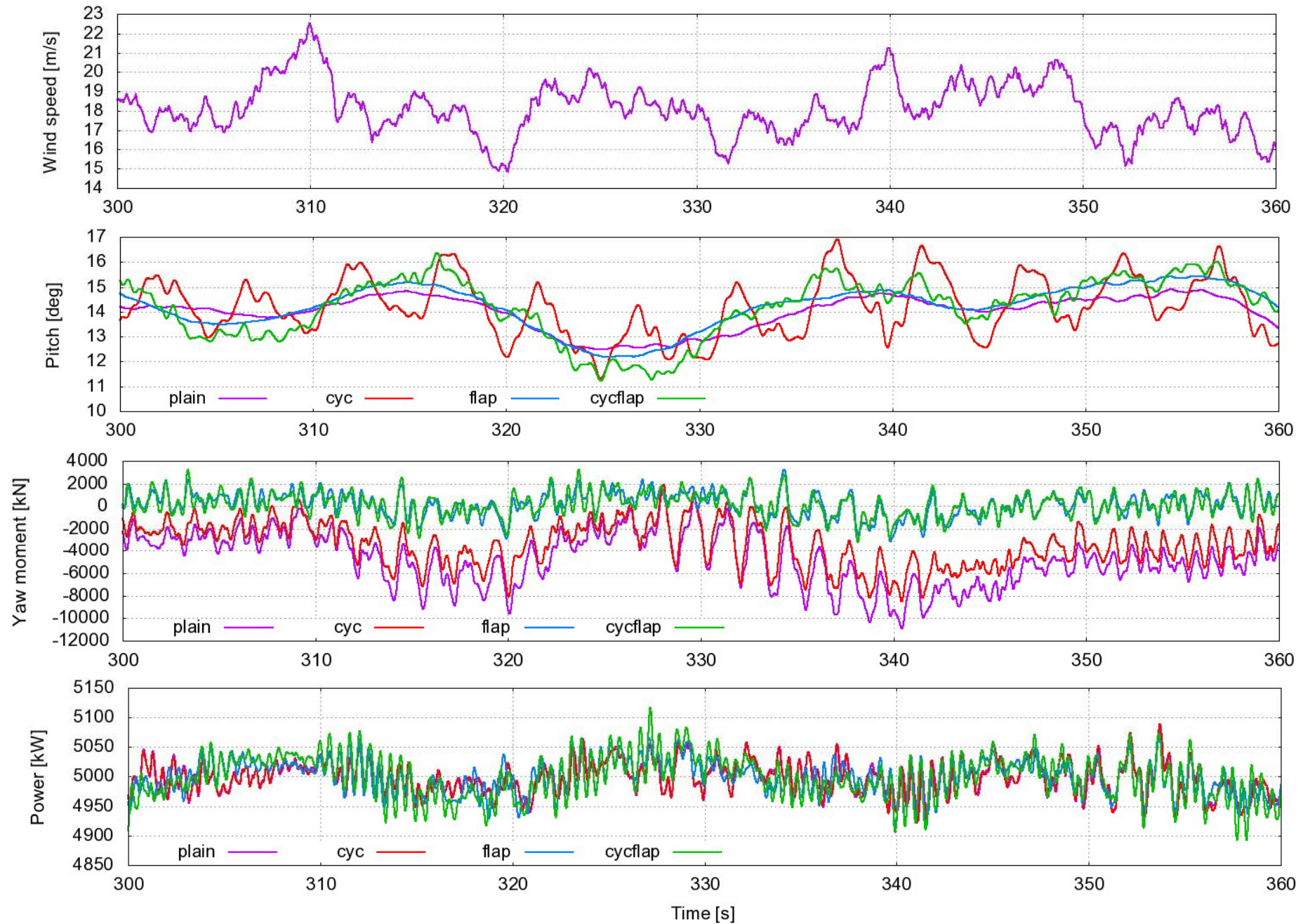














Introduction

Controller

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Conclusion

- The flaps with a ± 8 degree angle range seem to be able to eliminate almost all of the 30 degree yaw error
- Controllers needs to be integrated to see full potential
- Power production should be a part of the
- Tuning of controllers is very time consuming

Future work...

A “real” turbine

